CLAIMS

1. A reflective optical device, comprising two non-axisymmetric reflection surfaces for bringing light fluxes from an object into focus on an image surface, the two non-axisymmetric reflection surfaces being a first reflection surface and a second reflection surface, wherein:

the first and second reflection surfaces are disposed in this order in a direction in which the light fluxes travel, and are arranged eccentrically; and

each of the first and second reflection surfaces is concave in a cross-sectional shape taken along a plane containing a center of the image surface and vertices of the reflection surfaces.

2. The reflective optical device according to claim 1, further comprising a diaphragm for limiting light fluxes, the diaphragm being disposed between the first reflection surface and the object.

3. The reflective optical device according to claim 2, wherein a relationship expressed as below is satisfied:

$$0.3 < d1/efy < 1.5$$

where d1 represents a distance between a center of the diaphragm and the vertex of the first reflection surface, and efy represents a focal length in a plane containing the center of the image surface and the vertices of the first and second reflection surfaces.

4. The reflective optical device according to claim 2, wherein a relationship expressed as below is satisfied:

$$1.0 < d2/efy < 4.0$$

where d2 represents a distance between the vertex of the first reflection surface and the vertex of the second reflection surface, and efy represents a focal length in a plane containing the center of the image surface and the vertices of the first and second reflection surfaces.

5. The reflective optical device according to claim 1, wherein the first reflection surface is concave in a cross-sectional shape taken in a direction perpendicular to a plane containing the center of the image surface and the vertices of the first and second reflection surfaces.

6. The reflective optical device according to claim 1, wherein the second reflection surface is concave in a cross-sectional shape taken in a direction perpendicular to a plane containing the center of the image surface and the vertices of the first and second reflection surfaces.

7. The reflective optical device according to claim 1, wherein each of the first and second reflection surfaces is a free-form surface that does not have a rotational axis.

8. The reflective optical device according to claim 7, wherein the free-form surface is either a curved-axis Y toric surface or a curved-axis X toric surface, each of which is defined by a function f(X,Y) in a rectangular coordinate system (X, Y) in which the X direction is a direction perpendicular to a plane containing the center of the image surface and the vertices of the reflection surfaces and the Y direction is a direction of a tangent line at a vertex, the tangent line being contained in the plane,

the curved-axis Y toric surface being such that a line obtained by connecting centers of radii of curvature of X-direction cross sections at respective Y coordinates is a curved line,

the curved-axis X toric surface being such that a line obtained by connecting centers of radii of curvature of Y-direction cross sections at respective X coordinates is a curved line.

9. The reflective optical device according to claim 8, wherein the first reflection surface is a curved-axis Y toric surface or a curved-axis X toric surface, the curved axis-Y toric surface being such that a Y-direction cross section of the first reflection surface containing the vertex thereof is asymmetric with respect to a normal line at the vertex thereof, and a curved line connecting the centers of radii of curvature of the X-direction cross sections.

10. The reflective optical device according to claim 8, wherein the second reflection surface is a curved-axis Y toric surface or a curved-axis X toric surface, the curved axis Y toric surface being such that a Y-direction cross section of the first reflection surface containing the vertex thereof is asymmetric with respect to a normal line at the vertex thereof and a curved

line connecting the centers of radii of curvature of the X-direction cross sections.

11. A reflective optical device, comprising at least three reflection surfaces for bringing light fluxes from an object into focus on an image surface, wherein:

the reflection surfaces are arranged eccentrically;

an F value in a plane containing vertices of the respective reflection surfaces is less than 3.5; and

among the reflection surfaces, the two reflection surfaces on the object side are given as a first reflection surface and a second reflection surface, respectively, in an order from the object side in a direction in which the light fluxes travel, and each of the first and second reflection surfaces is concave in a cross-sectional shape taken along the plane.

12. A reflective optical device comprising at least three reflection surfaces for bringing light fluxes from an object into focus on an image surface, wherein:

the reflection surfaces are arranged eccentrically; and

an F value in a plane containing vertices of the respective reflection surfaces is less than 1.9.

13. The reflective optical device according to claim 12, wherein the F value is less than 1.6.

14. The reflective optical device according to claim 12, wherein, among the reflection surfaces, the two reflection surfaces on the object side are given as a first reflection surface and a second reflection surface, respectively, in an order from the object side in a direction in which the light fluxes travel, and each of the first and second reflection surfaces is concave in a cross-sectional shape taken along the plane.

15. A reflective optical device comprising at least three reflection surfaces for bringing light fluxes from an object into focus on an image surface, wherein:

the reflection surfaces are arranged eccentrically;

among the reflection surfaces, the reflection surface placed second

from the object side in a direction in which the light fluxes travel is given as a second reflection surface, and the second reflection surface is concave in a cross-sectional shape taken in the vicinity of its vertex along a plane containing vertices of the reflection surfaces, and is convex in a cross-sectional shape taken in a direction perpendicular to the plane.

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~~16. The reflective optical device according to any one of claims 11, 12,~~ and15, wherein the at least three reflection surfaces are ~~non~~-axisymmetric surfaces.

17. The reflective optical device according to any one of claims 11, 12, and 15, wherein the reflection surfaces are four surfaces that are a first surface, a second surface, a third surface, and a fourth surface in an order ~~from the object side in a direction in which the light fluxes travel.~~

18. The reflective optical device according to claim 17, wherein a relationship expressed as below is satisfied:

$$26 < \alpha 3 < 56$$

where $\alpha 3$ represents an angle (deg) formed between a normal line of the third reflection surface at its vertex and an optical axis extended from the vertex of the third reflection surface to a vertex of the fourth reflection surface.

19. The reflective optical device according to claim 17, further comprising a diaphragm for limiting the light fluxes, the diaphragm being disposed between the first reflection surface and the object.

20. The reflective optical device according to claim 19, wherein a relationship expressed as below is satisfied:

$$0.3 < d1/efy < 1.5$$

where d1 represents a distance between a center of the diaphragm and a vertex of the first reflection surface, and efy represents a focal length in the plane containing the vertices of the reflection surfaces.

21. The reflective optical device according to claim 19, wherein a relationship expressed as below is satisfied:

$$0.6 < d1/efy < 1.0$$

where d1 represents a distance between a center of the diaphragm and a vertex of the first reflection surface, and efy represents a focal length in the plane containing the vertices of the reflection surfaces.

22. The reflective optical device according to claim 19, wherein a relationship expressed as below is satisfied:

$$0.3 < d2/d4 < 1.0$$

where d2 represents a distance between a vertex of the first reflection surface and a vertex of the second reflection surface, and d4 represents a distance between a vertex of the third reflection surface and a vertex of the fourth reflection surface.

23. The reflective optical device according to claim 19, wherein a relationship expressed as below is satisfied:

$$2.6 < d4/efy < 7.5$$

where d4 represents a distance between a vertex of the third reflection surface and a vertex of the fourth reflection surface, and efy represents a focal length in the plane containing the vertices of the reflection surfaces.

24. The reflective optical device according to claim 19, wherein a relationship expressed as below is satisfied:

$$3.5 < d4/efy < 6.5$$

where d4 represents a distance between a vertex of the third reflection surface and a vertex of the fourth reflection surface, and efy represents a focal length in the plane containing the vertices of the reflection surfaces.

25. The reflective optical device according to claim 19, wherein a relationship expressed as below is satisfied:

$$0.5 < d5/efy < 2.0$$

where d5 represents a distance from a vertex of the fourth reflection surface to a center of an image surface, and efy represents a focal length in the plane containing the vertices of the reflection surfaces.

26. The reflective optical device according to claim 17, wherein each of the four reflection surfaces is concave in a cross-sectional shape taken along the plane containing the vertices of the reflection surfaces.

27. The reflective optical device according to claim 17, wherein, among the reflection surfaces, the first reflection surface is concave in a cross-sectional shape taken in a direction perpendicular to the plane containing the vertices of the reflection surfaces.

28. The reflective optical device according to claim 17, wherein, among the reflection surfaces, the third reflection surface is concave in a cross-sectional shape taken in a direction perpendicular to the plane containing the vertices of the reflection surfaces.

29. The reflective optical device according to claim 17, wherein, among the reflection surfaces, the fourth reflection surface is concave in a cross-sectional shape taken in a direction perpendicular to the plane containing the vertices of the reflection surfaces.

30. The reflective optical device according to claim 17, wherein the fourth reflection surface is a free-form surface that is in a non-axisymmetric form and that does not have a rotational axis.

31. The reflective optical device according to claim 17, wherein the fourth reflection surface is a free-form surface, and the free form surface is either a curved-axis Y toric surface or a curved-axis X toric surface, each of which is defined by a function f(X, Y) in a rectangular coordinate system (X, Y) in which the X direction is a direction perpendicular to a plane containing the center of the image surface and the vertices of the reflection surfaces and the Y direction is a direction of a tangent line at a vertex, the tangent line being contained in the foregoing plane,

the curved-axis Y toric surface being such that a line obtained by connecting centers of radii of curvature of the X-direction cross sections at respective Y coordinates is a curved line,

the curved-axis X toric surface being such that a line obtained by connecting centers of radii of curvature of the Y-direction cross sections at respective X coordinates is a curved line.

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~~32.~~ ~~An imaging device, comprising:~~

the reflective optical ~~device according to any~~ one of claims 1, 11, 12, ~~and 15; and~~

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~~a detecting means that converts a light intensity into an electric signal.~~

33. The imaging device according to claim 32, wherein the detecting means is a two-dimensional imaging element.

34. The imaging device according to claim 32, wherein the detecting means has sensitivity to light rays in an infrared range.

35. A multi-wavelength imaging device, comprising:

a reflective optical device that converges light fluxes with only reflection surfaces; and

a detecting means that has sensitivity to light rays in a plurality of different wavelength ranges.

36. The multi-wavelength imaging device according to claim 35, wherein the plurality of different wavelength ranges are not less than two wavelength ranges selected from an infrared range, a visible range, and an ultraviolet range.

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~~37. The multi-wavelength imaging device according to claim 35, wherein the reflective optical device is the reflective optical device according to any one of claims 1, 11, 12, and 15.~~

38. The multi-wavelength imaging device according to claim 35, wherein the detecting means includes a light flux separating means according to wavelengths, and a plurality of detecting surfaces that are responsive to the plurality of wavelength ranges, respectively.

39. The multi-wavelength imaging device according to claim 35, wherein the detecting means includes, in a same detecting surface, a plurality of regions that have sensitivity to light rays in different wavelength ranges, respectively.

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~~40. The multi-wavelength imaging device according to claim 39, wherein the reflective optical device is the reflective optical device according to any one of claims 1, 11, 12, and 15~~

41. A vehicle-mounted monitor, comprising:
an imaging device according to claim 32; and
a display means that conveys an obtained image to a driver.

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~~42. A vehicle-mounted monitor, comprising:~~
a multi-wavelength imaging device according ~~to claim~~ 35 or 39; and
~~a display means that conveys an obtained image to a driver.~~

43. A reflective optical device, comprising a plurality of optical members, each in a shell-like shape, that are opposed to each other and bonded integrally so that a hollow space is formed therein and that have at least one reflection surface on surfaces on hollow space sides.

44. The reflective optical device according to claim 43, wherein at least one of the reflection surface is a free-form surface that does not have a rotational axis.

45. The reflective optical device according to claim 43, wherein the plurality of optical members are two optical members that are a front optical member and a rear optical member, and the hollow space is formed by providing the front optical member and the rear optical member integrally so that an opened side of the shell-like shape of the front optical member and an opened side of the shell-like shape of the rear optical member face and are bonded to each other.

46. The reflective optical device according to claim 43, wherein:
the optical members are resin moldings; and
a metallic thin film is formed on the reflection surface.

47. The reflective optical device according to claim 46, wherein a material of the metallic thin film is at least one selected from the group consisting of aluminum, gold, silver, copper and zinc.

48. The reflective optical device according to claim 46, wherein a SiO_2 thin film also is formed over the reflection surface.

49. The reflective optical device according to claim 43, wherein the optical members are made of a metallic material.

50. The reflective optical device according to claim 49, wherein the optical members are made of at least one metallic material selected from the group consisting of aluminum, gold, silver, copper, and zinc.

51. The reflective optical device according to claim 49, wherein a metallic thin film is formed on the reflection surface of the optical members made of the metallic material.

52. The reflective optical device according to claim 51, wherein a material of the metallic thin film is at least one selected from the group consisting of aluminum, gold, silver, copper, and zinc.

53. The reflective optical device according to claim 49, wherein a SiO_2 film also is formed over the reflection surface.

54. The reflective optical device according to claim 43, wherein at least one of the plurality of optical members includes an aperture for image formation.

55. The reflective optical device according to claim 54, wherein a window member that transmits light fluxes in a wavelength range necessary for image formation is provided at the aperture for image formation.

56. The reflective optical device according to claim 54, wherein a window member that transmits light fluxes in a wavelength range necessary for image formation and that blocks light fluxes in the other wavelength ranges is provided at the aperture for image formation.

57. The reflective optical device according to claim 54, wherein a window member made of a material selected from the group consisting of germanium, silicon, polyethylene, CaF_2, BaF_2, and ZnSe is provided at the aperture for image formation.

58. The reflective optical device according to claim 55, wherein the window member is in a flat plate form.

59. The reflective optical device according to claim 55, wherein the window member has a lens function.

60. The reflective optical device according to claim 54, wherein a window member that has an optical property of preventing at least infrared rays in a specific wavelength range among incident infrared rays from passing therethrough is provided at the aperture for image formation.

61. The reflective optical device according to claim 60, wherein the window member has an optical property of reflecting infrared rays, and is composed of a transparent base on which a dielectric multi-layer film is provided.

62. The reflective optical device according to claim 61, wherein the transparent base is made of a glass material.

63. The reflective optical device according to claim 61, wherein the transparent base is made of a resin material.

64. The reflective optical device according to claim 61, wherein the transparent base is made of at least one selected from the group consisting of CaF_2, BaF_2, and ZnSe.

65. The reflective optical device according to claim 60, wherein the window member is made of a glass material having an optical property of absorbing infrared rays.

66. The reflective optical device according to claim 60, wherein the window member is made of a resin material having an optical property of absorbing infrared rays.

67. The reflective optical device according to claim 60, wherein the window member prevents infrared rays in a near infrared range from passing therethrough.

68. The reflective optical device according to claim 67, wherein the near infrared range is a range of 700nm to 1100nm.

69. The reflective optical device according to claim 60, wherein the window member is in a flat plate form.

70. The reflective optical device according to claim 60, wherein the window member has a lens function.

71. The reflective optical device according to claim 54, wherein a film having an optical property of not reflecting at least infrared rays in a specific wavelength range among incident infrared rays is formed on each reflection surface.

72. The reflective optical device according to claim 71, wherein the film has an optical property of not reflecting infrared rays in a range of wavelengths longer than those in a visible range.

73. The reflective optical device according to claim 72, wherein the range of wavelengths longer than those in the visible range is a range of wavelengths longer than 700nm.

74. The reflective optical device according to claim 71, wherein the film has an optical property of not reflecting infrared rays in a near infrared range.

75. The reflective optical device according to claim 74, wherein the near infrared range is a range of 700nm to 1100nm.

76. The reflective optical device according to claim 43, wherein at least one of the plurality of optical members includes an aperture for allowing an image to be formed on a member with photosensitivity.

77. A reflective solid-state optical device, comprising a solid device body formed with an optical medium having an optical property of preventing at least infrared rays in a specific wavelength range among incident infrared

rays from passing therethrough, wherein at least one reflection surface is formed on the device body, the reflection surface being composed of a surface of the device body and a film formed on the surface of the device body.

78. The reflective solid-state optical device according to claim 77, wherein the surface of the device body constituting the at least one reflection surface is formed to be a free-form surface that does not have a rotational axis.

79. The reflective solid-state optical device according to claim 77, wherein the optical medium is made of a material having an optical property of preventing infrared rays in a range of wavelengths longer than those in a visible range.

80. The reflective solid-state optical device according to claim 79, wherein the range of wavelengths longer than those in the visible range is a range of wavelengths longer than 700nm.

81. The reflective solid-state optical device according to claim 77, wherein the optical medium is made of a material having an optical property of preventing infrared rays in a near infrared range from passing therethrough.

82. The reflective solid-state optical device according to claim 81, wherein the near infrared range is a range of 700nm to 1100nm.

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~~83. An imaging device, comprising the reflective optical device according~~ to any one of claims ~~43 to 76,~~ wherein an imaging element is provided at a ~~portion of the reflective optical device where an image is formed.~~

84. The imaging device according to claim 83, wherein the imaging element has sensitivity to a visible range.

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~~85. An imaging device,~~ comprising the reflective optical device ~~according~~ to any one of claims 43 to 76, wherein an ~~imaging element~~ having sensitivity to a visible range is ~~provided at~~ a portion of the reflective optical device ~~where an image is formed.~~

86. An imaging ~~device, comprising the reflective~~ optical device according to any one of claims 43 to 59, wherein an imaging element having sensitivity to a visible range and an infrared range is provided at a portion of the reflective optical device where an image is formed.

87. An imaging device, comprising ~~the~~ reflective optical device according to any one of claims 67, 68, 74, ~~and~~ 75, wherein an imaging element having sensitivity to a visible range and an infrared range is provided at a portion of the reflective optical device where an image is formed.

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88. An imaging device, comprising the reflective solid-state optical device according to any one of claims 77 to 82, wherein an imaging element is provided at a portion of the reflective solid-state optical device where an image is formed.

89. The imaging device according to claim 88, wherein the imaging element has sensitivity to a visible range.

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~~90.~~ An imaging device, comprising the reflective solid-state ~~optical~~ device according to claim 81 or 82, ~~wherein an~~ imaging element having sensitivity to ~~a visible~~ range and an infrared range is provided at a portion of the reflective solid-state optical ~~device where an image is formed.~~

91. A video camera device, comprising the imaging device according to claim 83.

92. A video camera device, comprising the imaging device according to claim 88.

93. A vehicle-mounted monitor, comprising the imaging device according to claim 83.

94. A vehicle-mounted monitor, comprising the imaging device according to claim 88.

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